BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

B71 01012

SUBJECT: Abort Capabilities from Apollo 14 TLI Underburn Trajectories - Case 310

DATE: January 15, 1971

FROM: M. K. Baker

ABSTRACT

The SPS, DPS or SM/RCS can return the CSM to a safe earth entry if a TLI underburn occurs that exceeds the capability of the SPS to salvage a lunar landing for Apollo 14, launched on January 31, 1971. The SPS or the DPS provide sufficient ΔV to return the CSM safely to earth for any TLI underburn. In the event of premature shutdown during a SPS or DPS translunar abort the SM/RCS can provide a safe reentry.

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MEMORANDUM FOR FILE

A compromised Apollo 14 lunar landing mission, launched on January 31, 1971, is still possible even if the S-IVB can only inject the spacecraft into an elliptic trajectory with an apogee altitude greater than 105,000 nm.(1) This apogee corresponds to an S-IVB cutoff approximately 8 seconds prior to nominal cutoff. Figure 1 illustrates the apogee altitude achieved as a function of seconds of underburn.* If an early S-IVB shutdown occurs prior to 8 seconds from the nominal time, the mission will be aborted. This memorandum discusses the types of safe earth returns available if a TLI underburn should occur.

Underburn Trajectory Characteristics

Table I summarizes some parameters of the underburn trajectories including apogee and perigee altitudes and reentry conditions where applicable. Up to 2 seconds early S-IVB shutdowns result in circumlunar trajectories which reenter the earth's atmosphere. A 2-second early cutoff results in a circumlunar trajectory which is perturbed by the moon such that it becomes a very large ellipse (approximately 50,000 by 438,000 nm) with a period of 35 days. A 3-second early shutdown results in a circumlunar trajectory which does not reenter. Four to sixteen second underburns result in elliptic trajectories which do not enter the moon's sphere of influence.

Propulsion System Abort Capabilities

The maximum ΔV capabilities of the various propulsion systems that might be available for an abort are summarized in Table II. These ΔV capabilities include as usable propellant the 3σ dispersions propellant currently allotted for the SPS, the DPS and the APS.(2) The RCS capability is based on 975 lbs usable propellant.(3)

Abort Requirements

Figures 2 and 3 illustrate the minimum return to earth times for ΔV's of 140 fps, 2000 fps and 8000 fps corresponding roughly to cases 1, 2 and 4 of Table II. Figure 2 shows the

*The correspondence shown here between time of early S-IVB cutoff and apogee altitude varies slightly from the operational trajectory data due to differences in the simulation model. The results presented in the memorandum are valid for the apogee stated.

direct return abort possibilities if a mission salvage maneuver with the SPS did not take place. Either the SPS or the DPS can provide sufficient ΔV to obtain a direct safe return of the spacecraft to earth. Circumlunar aborts would also be feasible if a minimum time return were not indicated. RCS capability would probably be sufficient to make a circumlunar abort maneuver for some short period of time after TLI.

Figure 3 shows the aborts from the trajectories with less than 105,000 nm apogee. Additional data not shown in Figure 3 indicates that safe earth returns using only 75 fps are possible with maximum return times of 91, 81, and 40 hours at TLI + 3 hours for 7, 9, and 16 second underburns. The maximum reentry velocity constraint of 37,500 - 38,000 fps is not violated for any of the cases considered.

Figure 4 shows a generalized plot of the minimum return time data, that is, the fraction of the ellipse period it will take to return to earth for various ΔV's capabilities. This is mission independent and can be used to estimate return time from any geocentric ellipse with perigee altitude of $\sim$90 nm.

The abort data shown in Figures 2 and 3 are for unrestricted earth landing points. These landing points sweep across the major land masses: Australia, Africa, and South America. Thus, in some cases to avoid land landings a slightly longer than minimum return time must be employed or the time of the abort maneuver must be delayed. For a maximum abort ΔV of 8000 fps the required delay can be as long as two hours.

Premature Shutdown During an Abort Maneuver

Since the amount of ΔV used determines the time of flight from the maneuver to earth landing, varying the magnitude of a burn will change the earth landing point. A representative case, abort at TLI + 10 hours, has been examined to determine the ΔV cost of obtaining a midpacific landing and the effect of an early cutoff during the abort burn. Table III summarizes the necessary ΔV for a midpacific landing and the corrective ΔV necessary to obtain a water landing if an early shutdown occurred during the abort burn. For example, if there were an 8-second TLI underburn, 3000 fps at TLI + 10 hours would be required to achieve a midpacific landing. If there were an engine failure during the abort and only 2000 fps were obtained, the spacecraft would reenter but would land in the Indian Ocean. If only 1000 fps were obtained during the maneuver, the spacecraft would not reenter and an additional maneuver would be necessary. It should be noted that a premature shutdown during the abort burn would almost always require an additional trim maneuver to obtain a reentry flight path angle consistent with mission constraints. For any abort underburn, including those aborts targeted for 8000 fps, the SM/RCS can provide sufficient ΔV to obtain reentry; however, a water landing cannot be guaranteed in all cases. Consider the case of an 8-second TLI underburn trajectory shown in Table III. Premature abort shutdowns between 2000 fps and 1000 fps would require the spacecraft to land on Australia. The SM/RCS capability is not sufficient to give longitude control of greater than 10° regardless of when the RCS maneuver takes place. Figure 5 illustrates the SM/RCS ΔV capability for CSM only and CSM + LM configurations as a function of the magnitude of the SPS or DPS abort burn.

Summary

All underburn trajectories examined are DPS or SPS abortable. SM/RCS can provide abort capability for trajectories resulting from greater than 7-second underburns. If an abort burn of 8000 fps were targeted at TLI + 10 hours and an early engine cutoff occurred, the SM/RCS could safely return the spacecraft to earth with a possible water landing.

M K Baker
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2013-MKB-slr

Attachments

REFERENCES

1. Berry, Ronald L., TLI GO/NO-GO Minimum landing mission for Apollo 14, 70-FM54-234, October 13, 1970.

2. Apollo Spacecraft Weight Status Summary, December 15, 1970.

3. Stern, R. J., Preliminary Evaluation of SM/RCS Capability to Abort to Earth Entry from the Relaxed Free Return Profile, Bellcomm Memorandum for File B70 09084, September 30, 1970, Case 310.

TABLE I

UNDERBURN TRAJECTORY CHARACTERISTICS

Seconds of Underburn	Reentry		Perigee* alt(nm)	Apogee alt(nm)	Periselene alt(nm)
	?	Flight Path Angle			
1	Yes	-20.4			3,000
2	No				4,200
3	No				22,200
4	Yes	-25.8		160,700	
5	Yes	-24.6		142,600	
6	Yes	-19.2		128,500	
7	Yes	-14.9		116,900	
8	Yes	-11.6		107,200	
9	Yes	-8.9		99,000	
10	Yes	-6.7		91,900	
11	Yes	-4.7		85,700	
12	Yes	-2.5		80,300	
13	No		69	75,500	
14	No		78	71,200	
15	No		85	67,300	
16	No		90	63,800	

*Perigee altitude on earth return leg.

TABLE II

MAXIMUM ΔV AVAILABLE DURING TRANSLUNAR COAST
(INCLUDING 3σ DISPERSIONS)

Option	Source of Propulsion	Abort Configuration	Available ΔV
1	SM RCS	CSM	140
2	DPS	CSM + LM	1,990
3	SPS	CSM + LM	5,310
4	DPS + SPS	CSM + LM	9,030
5	DPS + SPS	CSM	11,835
6	SPS	CSM	9,845
7	SPS + DPS	CM + LM	10,150
8	DPS	CM + LM	4,825
9	DPS + APS	CSM + A/S	2,690

TABLE III

REPRESENTATIVE ABORTS TO MIDPACIFIC SHOWING EFFECT OF EARLY ABORT CUTOFF

TLI Underburn (sec)	ΔV Required At TLI+10 HRS To Land Between 150°W and 170°W (fps)	If Early Cutoff						Water Landing
		Return Time (hr)	Actual ΔV Achieved (fps)	Reentry With No Maneuver ?	RCS Capability (fps)	Minimum ΔV Required for Correction at TLI+12 (fps)	Return Time (hr)	
6	3680	31.0						
			2680	Yes	176	25	37	89 E*
			1680	No	160	25	51	112 W**
			680	No	146	25	76	130 W**
8	3000	31.8						
			2000	Yes	164	25	39	79 E*
			1000	No	150	25	54	149 W**
12	1840	31.5						
			840	No	148	25	39	77 E*

*Indian Ocean
**Pacific Ocean

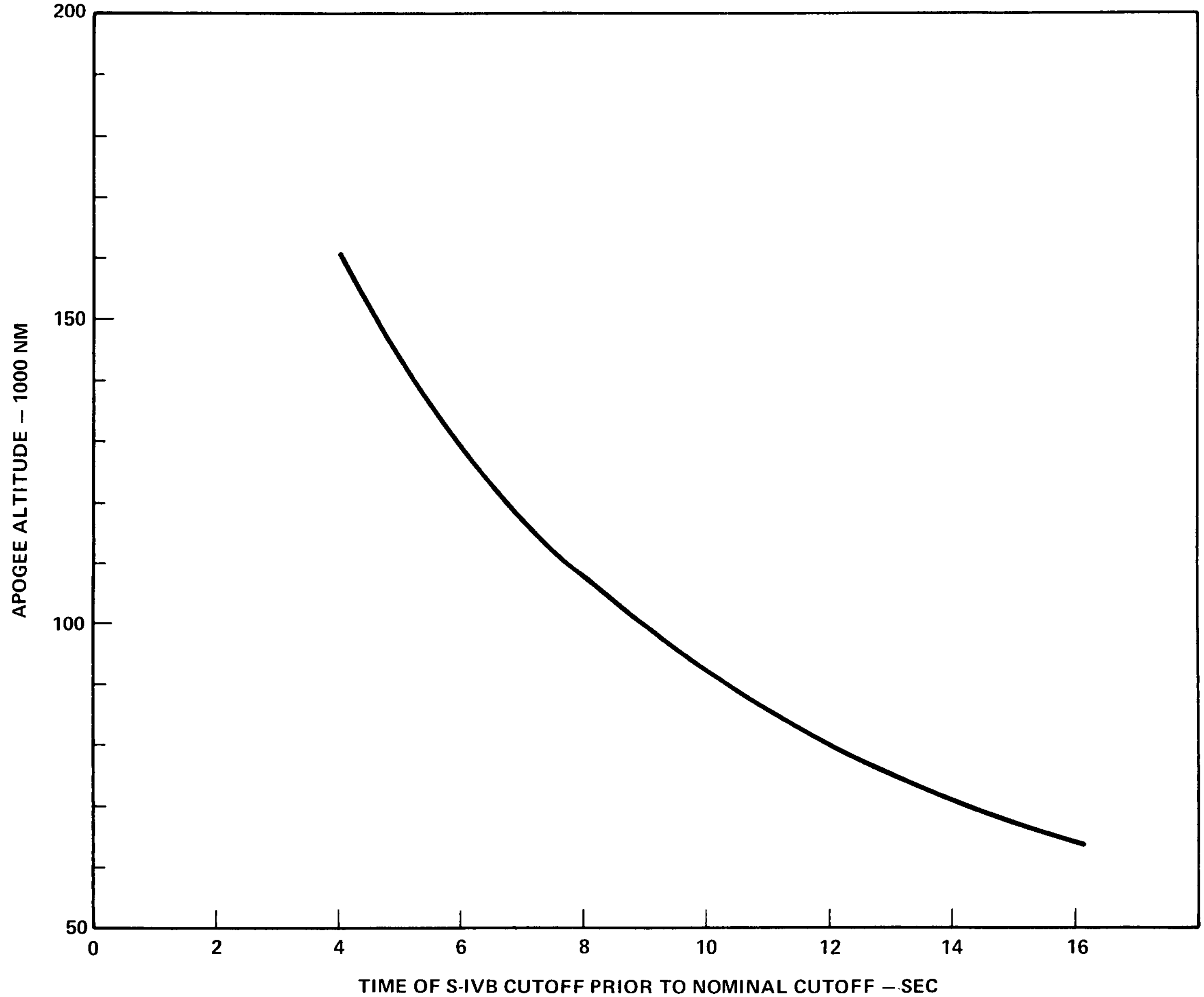

FIGURE 1 - APOGEE ALTITUDE OF UNDERBURN TRAJECTORIES

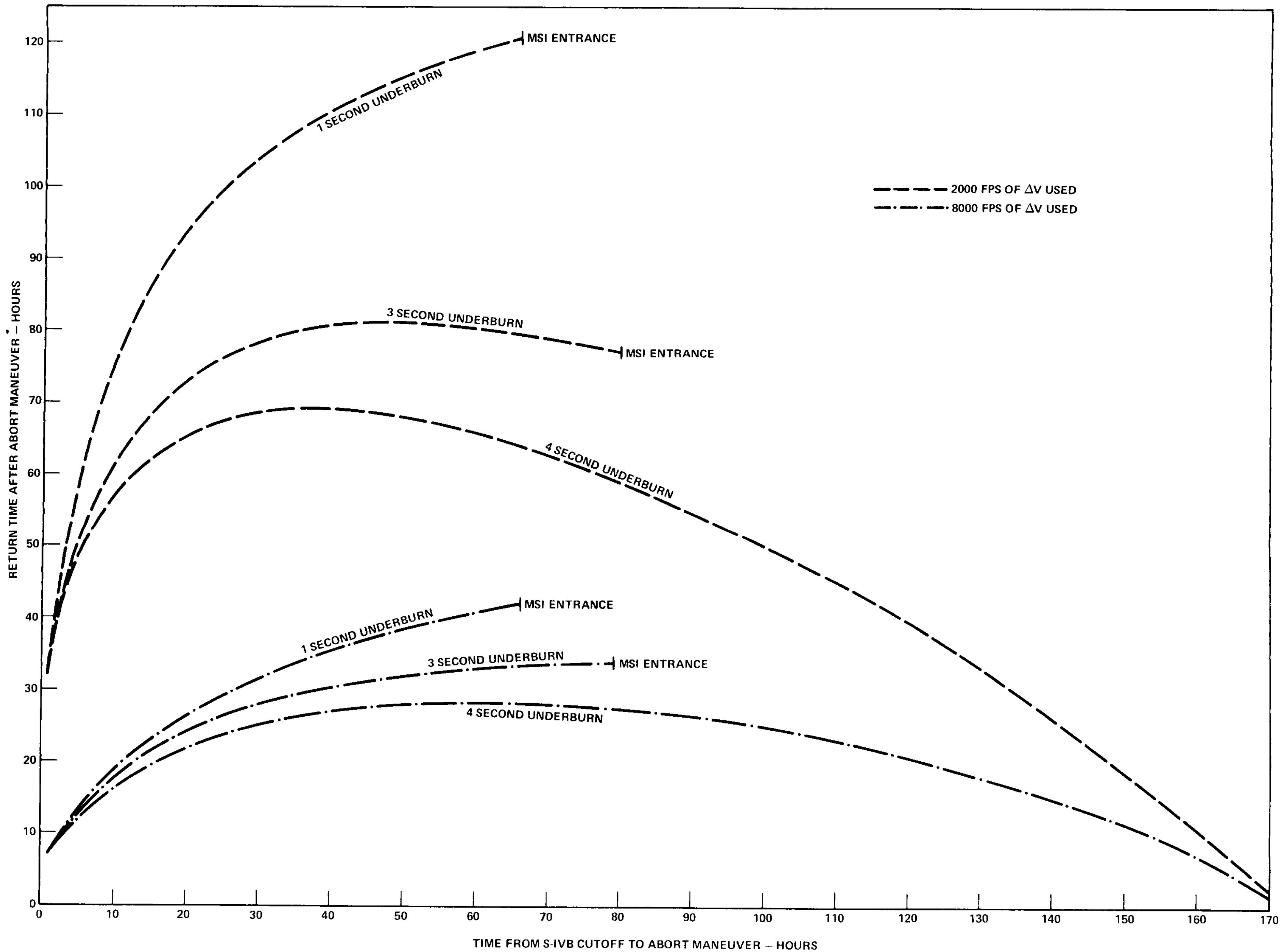

FIGURE 2 - MINIMUM TIME ABORTS FROM UNDERBURN TRAJECTORIES – FRA MAURO LAUNCHED 1/31/71

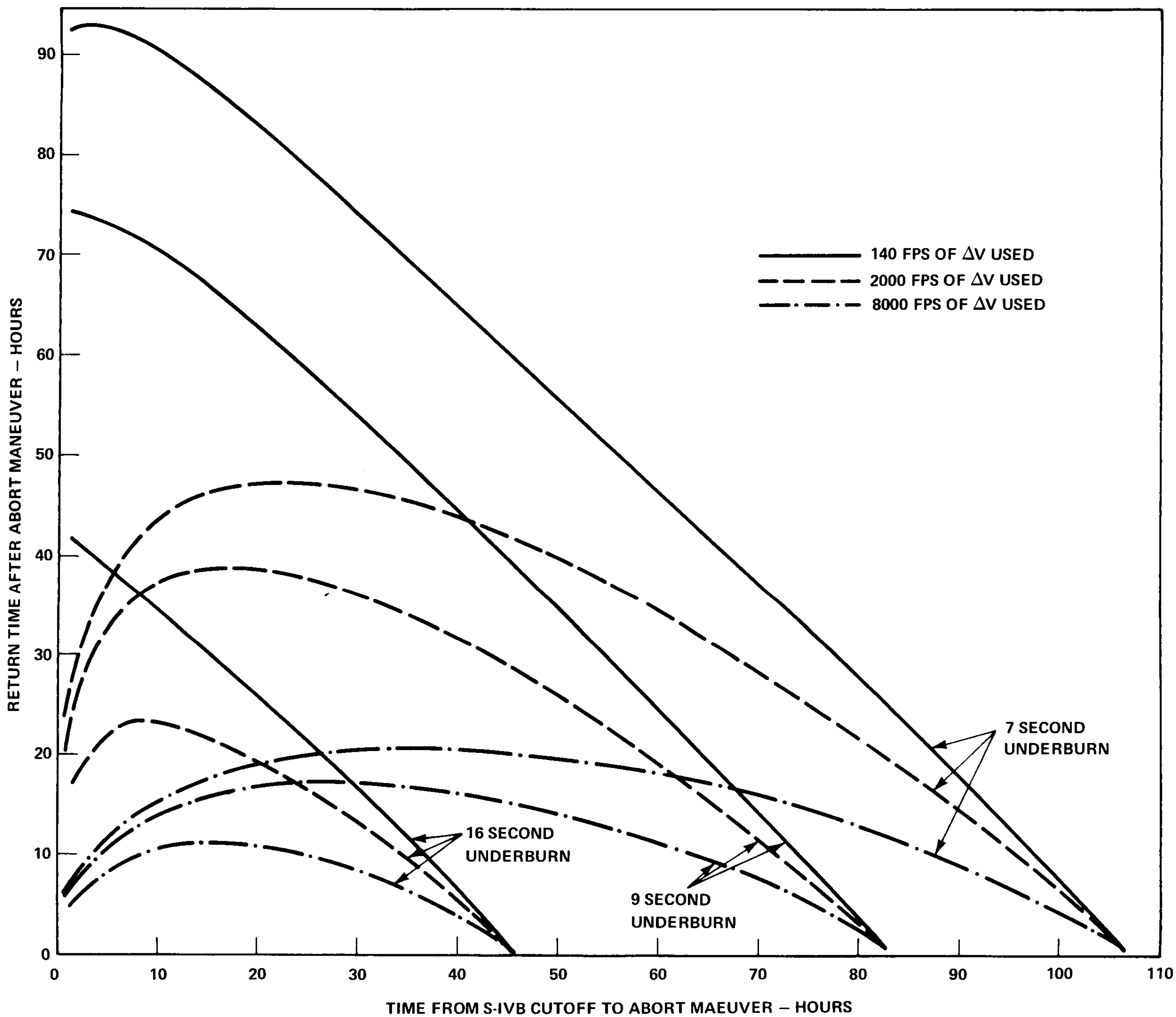

FIGURE 3 - MINIMUM TIME ABORTS FROM UNDEBURN TRAJECTORIES
FRA MAURO, LAUNCHED 1/31/71

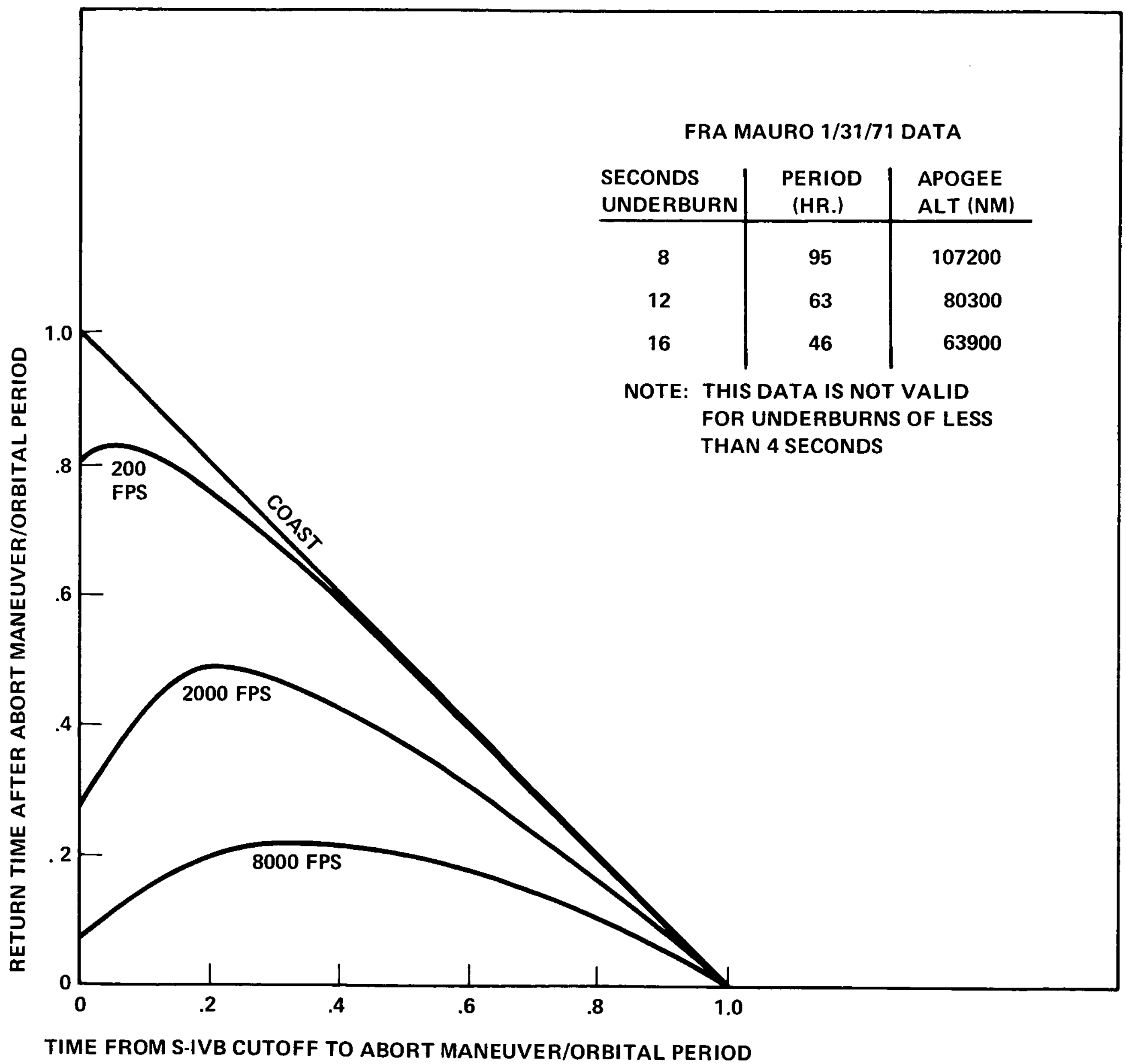

FIGURE 4 - APPROXIMATE NORMALIZED RETURN TIMES FROM TLI UNDERBURNS: MISSION INDEPENDENT

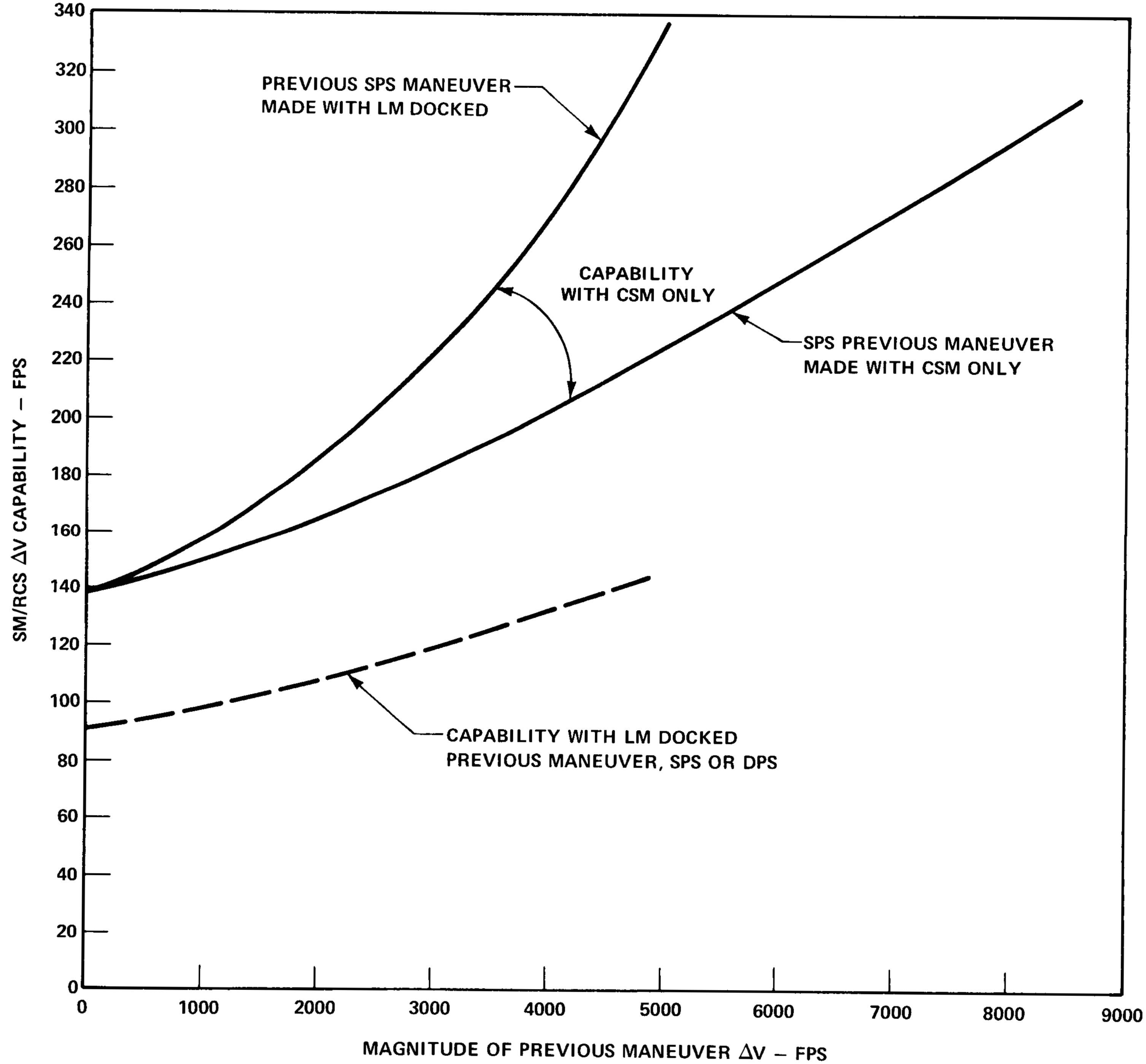

FIGURE 5 - RCS ΔV CAPABILITY IF A PREVIOUS DPS OR SPS MANEUVER HAS BEEN MADE

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